Traffic Jam Minimization and Accident Avoidance System Using IoT

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Abstract. Traffic jam is one of the biggest challenges of 21st century and hence there is an urgent need to combat the issue of vehicular congestion. It can be classified by Department of Transportation as 'recurring' which includes bottlenecks, narrow roads etc. and 'non-recurring' which consists of temporary disruptions like accidents, weather etc. With the emergence of 4G/5G technology, the Internet of Things (IoT) has grown exponentially, thus facilitating real time transfer of data bits. The indulgence of the IoT for the vehicular movement can be used to minimize the traffic congestions. A two-way communication is established between the vehicles in its local vicinity and the critical information flows between them, in real time. In this paper, a concept has been proposed that will attempt to minimize the traffic congestion by using IoT. The proposed concept will handle the safety of the vehicles thus reducing the probability of accidents and will minimize the traffic jam especially 'phantom jam'. Google Map API's will be integrated for retrieving data of structure of the roads and for the performance analysis. To elucidate the proposed concept, algorithms for maintaining a threshold distances between vehicles, overtaking and lane changing are presented in this paper.

Keywords: Internet of Things (IoT), Traffic Jam, Vehicular Congestion.

1 Introduction

According to the statistics 78.6 million automobiles have been sold in 2018 worldwide [1]. A mathematical explanation for the occurrence of traffic congestion was proposed by Boris Kerner. The proposed traffic theory comprises of three phases namely Free Flow, Synchronized Flow and Wide Moving Jams [2]. The widening of the roads has been established in order to minimize traffic jams but recent studies has shown that after the widening of the roads the density of the vehicles or automobiles increases, thus grasping a threshold point where the jams are again meant to happen [3]. Sometimes there are no causes such as closed lanes, accidents or bad weather still there is congestion on the roads, this phenomenon is called 'Phantom Jams' [4] which was termed by the researchers at Massachusetts Institute of Technology (MIT). It is caused due to hard hitting of brakes or two or more vehicles getting too much close to each other maintaining a small space in between. According to the Department of Transportation traffic

jams are classified as ‘recurring’ and ‘non-recurring’. Recurring traffic congestion is caused due to high density of vehicles than the roads can accommodate. Non-recurring traffic congestion is triggered due to environment, mechanical issues and humans [5]. The environmental issues incorporate rain, fog, snowstorm, etc. the mechanical issues involve breaking down of car or accidents and the humans are the main reason as there are many cases of drunk driving or emotional driving according to the National Highway Traffic Safety Administration [6]. With the emergence of Internet of Things (IoT), it is possible to minimize the congestion as the vehicles will be connected to each other in its zone sharing critical information and calculating some variables. Those variables include the distance that needs to be maintained between the vehicles, the limit of speed up to which the driver must drive the automobile, the current speed of the vehicle, etc. The transfer of that critical information or data bits prerequisites to be fast enough with minimal transfer delay which can be attained by 4G/5G network communication.

1.1 Research Motivation

The automated vehicles use mechatronics, artificial intelligence and multiagent system and its autonomy levels are from 0 to 5, where Level 0 means no automation, Level 1 means driver assisted, Level 2 means partial automation, Level 3 means conditional automation, Level 4 means high automation and Level 5 means full autonomy [7]. Level 0, Level 1 and Level 2 are more prone to accidents as the vehicle is under the direct control of the driver while as the Level 3, Level 4 and Level 5 are less prone to accidents because the vehicles are programmed and not under direct influence of the driver. Level 3, Level 4 and Level 5 vehicle automation can’t be completely applied in the urban and rural areas of developing countries like Brazil, India, Pakistan, South Africa, [8] etc. Thus, an innovative touch needs to be integrated in the Level 2 automation where the vehicle is controlled by the driver. The proposed innovative touch which consists of algorithms and flowcharts are explained in the later section of the paper, which when implemented will reduce the probability of traffic jams especially Phantom Jams or Jamitons and will also minimize the probability of accidents caused due to overtaking on a one-way road structure with many lanes.

2 Related Work

If every vehicle is replaced with the automated vehicle, the traffic jam will be completely eradicated but this scenario is not possible. The automated vehicle is programmed according to the rules and regulations of the Department of Traffic. Rules are transformed into equations which is later imposed via any programming language. On the basis of Level 3, Level 4 and Level 5, self-driving car or robotic car is a vehicle that is capable of sensing its environment with little or no human input [9]. In self driving cars common positioning system is based on the satellite technology such as GPS, Galileo, GLONASS [10]. The technology proposed as Connected Vehicle Technology is advantageous for the movement of traffic at the intersections [11], which provides an efficient signal control strategy. The authors have also proposed a fast branch and

bound algorithm for the improvement of the computational efficiency leading to reduction in delays and stops.
Fuzzy logic can be used to control the trajectory of automated vehicles with a centralized controller. Alternative track prediction, keeping a safe distance between vehicles and integrating night vision using infrared cameras can be achieved using fuzzy logic [12].The author has developed ethical crashing algorithms using Guided Track systems for avoiding collisions. The rational approach is integrated with artificial intelligence approach, and a natural language requirement. The automated automobile predicts various alternative crash paths and a path is selected on the basis of lowest damage or likelihood of collision. Waymo [13] which was set in motion as a project of Google self-driving technology development company. The technology is in testing phase; it has passed the tests and has been employed in certain environments but yet it has to pass the tests in harsh environments.

3 Proposed model

The proposed model can be implemented via MATLAB and its components related to the Driving Scenario Simulation. The MATLAB code created during the implementation of the proposed algorithms presented in this paper needs to be tested. The first testing phase can be conducted using MATLAB performance testing framework which includes performance measurement-oriented structures [14] and the second testing phase can be conducted by integrating Google Map API. The infrastructure of roads based on the Google Maps will be used to simulate the scenario and the road structures are selected in the series of distinct stages. First those structures are selected which will be easy to simulate the scenario and after passing the previous structure, more difficult environment is selected on the Google Maps. The efficiency of the algorithm after deep deliberation and study of research of various researchers in this field, a model is proposed that is going to work on the following algorithms and flowcharts.

3.1 Proposed Algorithm and Flowchart for Maintaining a Threshold Distance Between Two Vehicles

Algorithm 1. Maintaining a minimum distance between the vehicles reduces the probability of Phantom Jams or Jamitons. The algorithm regarding to the maintenance of a minimum distance is given as follows:

Vehicle at front = v_1
Vehicle at back = v_2
Speed of v_1= Sp_{v1}
Speed of v_2= Sp_{v2}
A point p is selected by $v_1$as starting point
While, Time t_n where $n \geq 0$
Distance, $d_{v1}$from point $p = d_{v1} + \int_{tn}^{tn+5} vdt$ (velocity of v_1)
Distance, $d_{v2}$from point $p = d_{v2} + \int_{tn}^{tn+5} vdt$ (velocity of v_2)

Distance, $dist$ between v_2 and v_1= $d_{v2} - d_{v1}$
If $dist \leq length\ of\ v_2$
Then "v_2 has to decrease the speed"
Else
"Depends upon the driver of v_2"
Time is incremented $t_n = t_{n+5}$
End While

Flowchart 1. The flowchart regarding to the algorithm for maintaining a threshold distance between vehicles are given as:

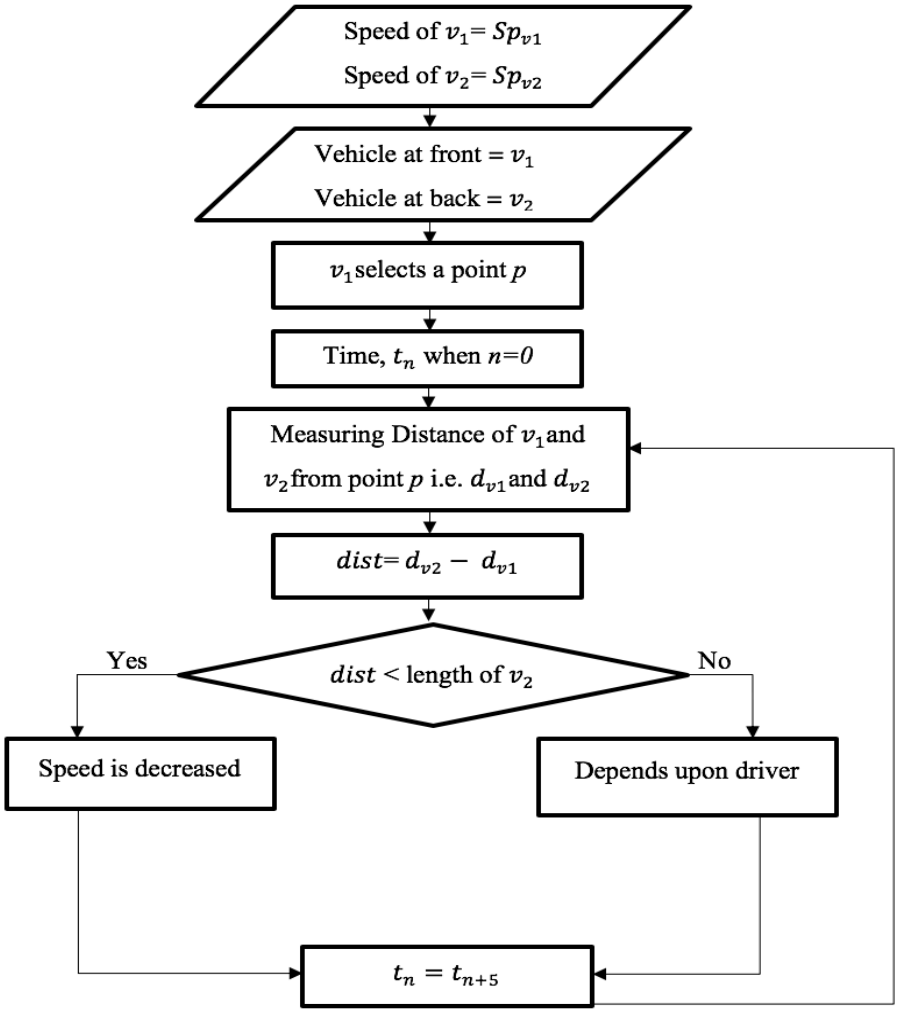
Speed of v_1= Sp_{v1}
Speed of v_2= Sp_{v2}
Vehicle at front = v_1
Vehicle at back = v_2
$v_1$selects a point p
Time, t_n when n=0
Measuring Distance of $v_1$and $v_2$from point p i.e. $d_{v1}$and d_{v2}
$dist$= $d_{v2} - d_{v1}$
Yes
$dist$ < length of v_2
No
Speed is decreased
Depends upon driver
$t_n = t_{n+5}$

Fig. 1. Maintaining a threshold distance between two vehicles.

3.2 Proposed Algorithm and Flowchart for Overtaking

Algorithm 2. Controlling overtaking will reduce the probability of fatal accidents, thus an algorithm has been fabricated which is as follows:

Vehicle that wants to overtake= v_0
Vehicles in other lane= v_l
Number of vehicles, $v_0$has to overtake=n
Vehicle that are present at the front of v_0= v_n
Algorithm 1 between $v_n$and v_{n+1}

Distance of v_0= d_{vo}
Distance of vehicle present at the front of v_0 = d_{vn}
Initial value, n = 1

While $n \leq 3$

If
$dist > length\ of\ v_0 + \frac{length\ of\ v_0}{2} = \delta$
Overtaking is initiated at time T
Else $n++$

If $n > 3$"overtaking not possible"
End While

In other lane
Applying algorithm 1 to v_0 , $v_1$and v_l
Distance covered by any vehicle in other lane= d_{vl}

For
$d_{vn} + length\ of\ v_n < d_{vl}$
Or
$d_{v0} - length\ of\ v_0 > d_{vl}$
"Permission for overtaking is granted to v_0"
Else
"Permission for overtaking isn't granted to v_0"
End For

If $d_{v0} > d_{vn}$
"overtake successful"

Flowchart 2. The flowchart considering the algorithm for overtaking is given as follows:

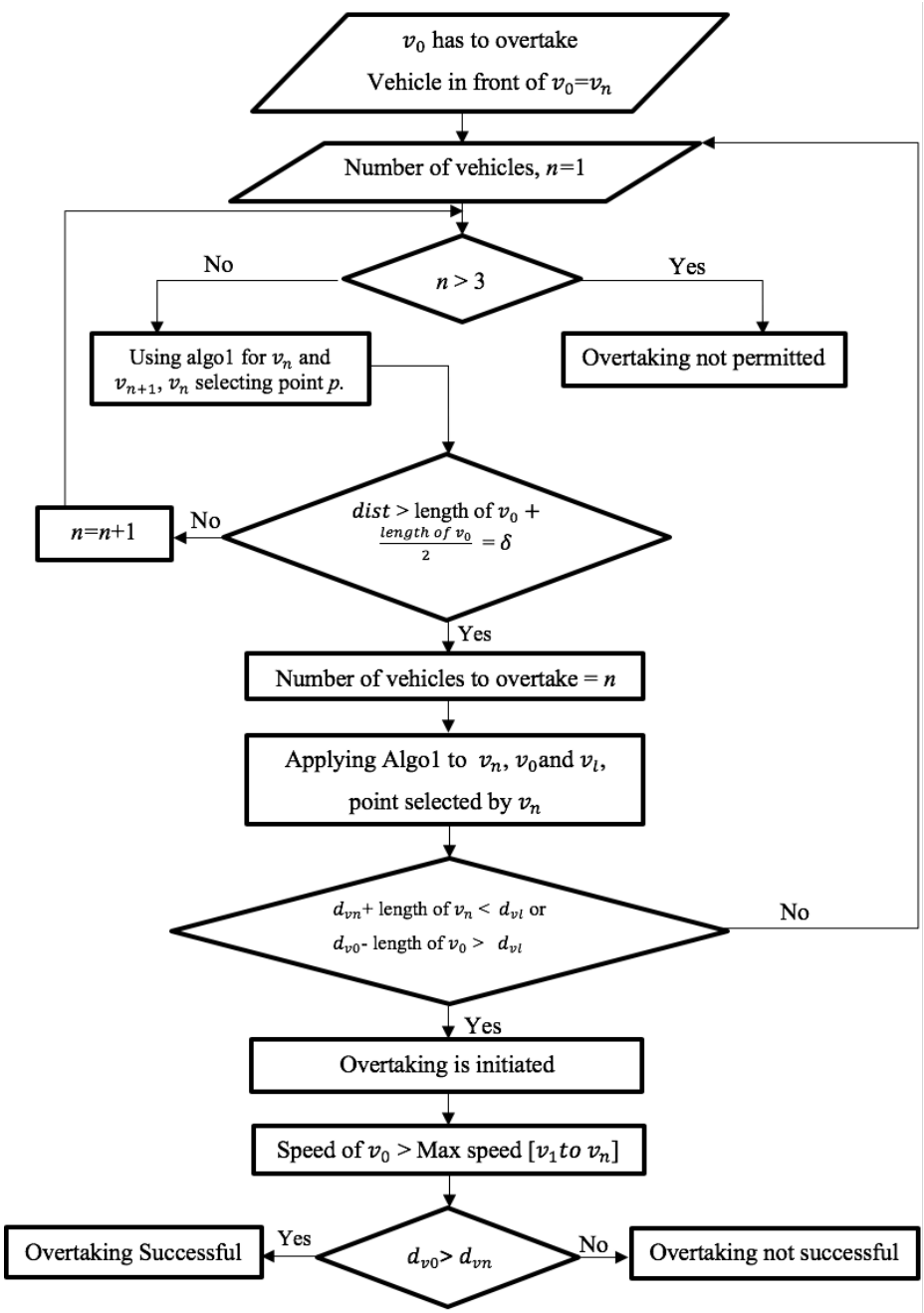

Fig. 2. Overtaking on a one-way road with more than one lane.

3.3 Proposed Algorithm and Flowchart for Lane Shifting

Algorithm 3. Controlling the changing of the lanes can further help in minimizing traffic jams and accidents. The algorithm for lane shifting is as follows:

Vehicle that wants to change lane= v_0
Vehicles in other lane in the zone of v_0= v_l
In other lane
Applying algorithm 1 to v_0 and v_l;point selected by v_0
Distance travelled by v_0 = d_{vo}
Distance travelled by v_l = d_{vl}

While
d_{vo}+ length of $v_0 < d_{vl}$ or
d_{vo}- length of $v_0 > d_{vl}$
"Lane changing is permitted to v_0"
End While

Flowchart 3. The process flow for shifting the lane is given in following flowchart:

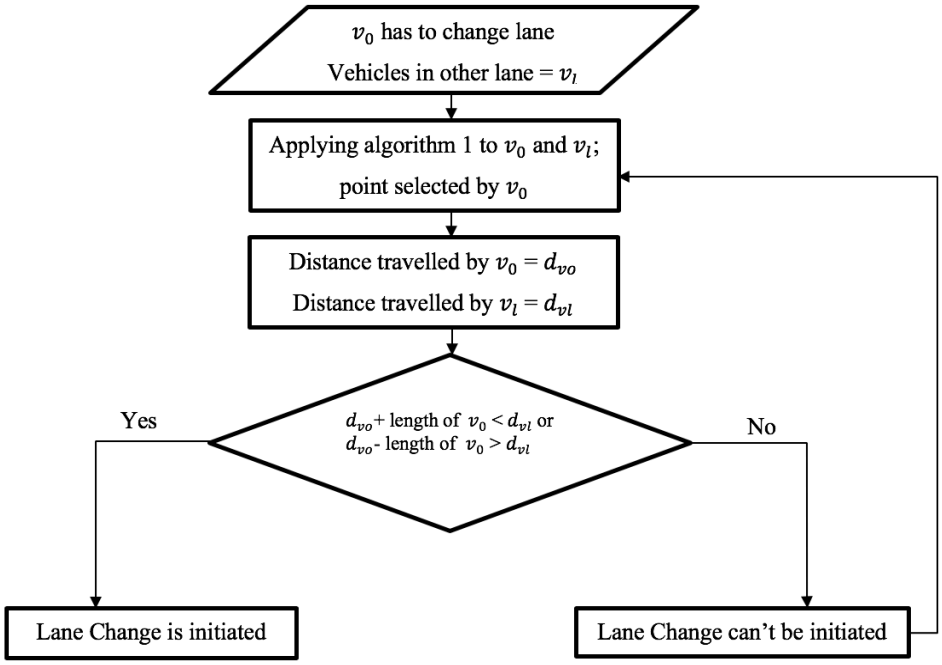
v_0 has to change lane
Vehicles in other lane = v_l
Applying algorithm 1 to v_0 and v_l;
point selected by v_0
Distance travelled by v_0 = d_{vo}
Distance travelled by v_l = d_{vl}
d_{vo}+ length of $v_0 < d_{vl}$ or
d_{vo}- length of $v_0 > d_{vl}$
Yes
No
Lane Change is initiated
Lane Change can't be initiated

Fig. 3. Lane Shifting on a one-way road

4 Discussion

The main reason for traffic jams are overtaking and lane changing which can be avoided by the communication of vehicles in their vicinity using IoT, sharing the real time value of variables for individual calculation in each component or vehicle. Hard hitting of brakes arises jamitons which can be avoided by keeping a safe distance between the vehicles. The further explanation on the basis of previous algorithms for the maintenance of threshold distance between vehicles, overtaking and lane changing in this paper are as follows:

4.1 Maintaining a Threshold Distance Between Two Vehicles.

For the sake of understanding, a small system of 2 vehicles are taken in consideration. The vehicle at the front is denoted by v_1 and the vehicle at the back is denoted by v_2 as shown in figure 1. The speed of both vehicles will be given as Sp_{v1} and Sp_{v2}, respectively. $v_1$select a point p as a starting point and this point is the latitude and longitude which is selected on the GPS connected to the system at a specific time, t_n where n is equal to zero. The loop starts at this point applying the increment after obtaining the distance first time. The distance d_{v1} of the vehicle $v_1$is measured from that point using equation.

$$d_{v1} = d_{v1} + \int_{tn}^{tn+5} vdt \,(1)$$

Other vehicles v_2 travels through same point i.e. same latitude and longitude and its distance d_{v2} is measured by the equation

$$d_{v2} = d_{v2} + \int_{tn}^{tn+5} vdt \,(2)$$

Distance $dist$ between v_1 and v_2 is measured by subtracting d_{v1} from d_{v2}. The $dist$ should always be greater than $length\ of\ v_2$ between v_1 and v_2. If the distance is less than the threshold value then the driver has to apply the brakes decreasing the speed and maintaining the $dist$ of more than threshold value which is $length\ of\ v_2$. The time t is incremented by the value of five seconds i.e. t_{n+5} and the loop starts again.

4.2 Overtaking

The vehicle that wants to overtake is denoted by v_0 and the vehicles present in front are denoted by v_{1-n} where max value of n depends upon the vehicles v_0 has to overtake. Let T be the time of the initiation of the process. Using algorithm 1 distance is measured between v_n and v_{n+1} where initial value of $n = 1$.

$$\delta = (length\ of v_0 + \frac{length\ of\ v_0}{2})(3)$$

If the $dist$ is greater than δ, then the number of vehicles to overtake will be equal to the recent value of n and if the $dist$ is less than δ, n is incremented by 1 which means the next vehicle is checked for δ. The loop continues until the condition of $n = 3$ is met which means max number of vehicles to overtake is 3. When $n > 3$, v_0 doesn't get any acknowledgement. If the conditions are satisfied, an acknowledgement is received by v_0 and the acknowledgement is sent by the vehicle that finds the δ. The last value of n denotes the number of vehicles that will be overtaken by v_0. The vehicles in the other lane is the zone of v_0 is checked for distance and algorithm 1 is applied. If the distance covered by any vehicle in that zone is greater than the distance covered by $(v_n + length\ of\ v_0)$ and less than $(\delta - length\ of\ v_0)$ then the overtake is possible and the driver will get the permission of overtaking else the overtaking is not possible and the process starts again until δ is found. During the process of overtaking in the other lane which has covered distance more than $(v_n + length\ of\ v_n)$ and less than $(\delta -$ length of $v_0)$ has to maintain the speed that was recorded at time T i.e. the initialization of the overtaking process. The maximum of the speed of vehicles from $v_1 to\ v_n$ is taken in consideration and v_0 has to maintain the speed greater than that. For checking the successful completion of the overtaking process, the distance covered by v_0 i.e. d_{v0} must be greater than the distance covered by v_n i.e. d_{vn}.

4.3 Lane Changing

The vehicle that wants to change lane is denoted by v_0 and its local zone or local vicinity is selected. If the distance covered by any vehicle in the second lane in that zone is greater than the distance covered by $(v_0 + length\ of\ v_0)$ and less than $(v_0 - length\ of\ v_0)$ then the lane changing is possible and the driver will get the permission of changing lane else it is not possible. The condition is checked in a loop until the lane changing procedure is completed.

5 Conclusion and Future Scope

The changing of lanes, overtaking and upholding a threshold distance between vehicles can help the transportation department to minimize the traffic congestion or 'jamitons' which are termed by researchers while researching on the causes of traffic jams. If any driver of the vehicle doesn't follow the result of the algorithms then an alert message will be received by Department of transportation with information about the vehicle and its owner via Internet of Things (IoT) as its technology for the communication between the vehicles. The system can be implemented in real life by programming Raspberry Pi in an IoT environment [15] integrating Google Map's API. In future, the algorithm can be developed for the intersection and for the turning points thus decreasing the probability of jamitons and fatal accidents in level 2 vehicle automation. The speed of the transfer of critical information which has been discussed in this paper must be in real time or with a minimal delay. This can be attained by using 5G/4G where delay is much less and transfer happens in real time [16].

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